Thin-ice Arctic Acoustic Window (THAAW)

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Award Number: N00014-12-1-0226

LONG-TERM GOALS

The Arctic Ocean is currently undergoing dramatic changes, including reductions in the extent and thickness of the ice cover and extensive warming of the intermediate layers. The multiyear ice is melting. Ice keels are getting smaller. With more open water, the internal wave energy level and therefore acoustic volume scattering are likely increasing, at least during summer. What was learned about acoustic propagation and ambient noise in the Arctic during the Cold War is now obsolete.

The long-term objectives of this research program are to understand the effects of changing Arctic conditions on low-frequency, deep-water propagation and on the low-frequency ambient noise field. The goal is to determine the fundamental limits to signal processing in the Arctic imposed by ocean and ice processes. The hope is that these first few new steps will lead to a larger, permanent acoustic monitoring, communications, and navigation network in the Arctic Ocean (Mikhalevsky *et al*., 2014).

This research effort was funded as an expansion of ONR Grant N00014-12-1-0226, entitled “North Pacific Acoustic Laboratory: Deep Water Acoustic Propagation in the Philippine Sea.” This annual report is in addition to the annual report for ONR Grant N00014-12-1-0226 that describes the research effort in the Philippine Sea.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2014**	2. REPORT TYPE	3. DATES COVERED **00-00-2014 to 00-00-2014**
4. TITLE AND SUBTITLE **Thin-ice Arctic Acoustic Window (THAAW)**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of California San Diego,Scripps Institution of Oceanography,9500 Gilman Drive,La Jolla,CA,92093**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

OBJECTIVES

The THAAW project is a preliminary experiment to make acoustic propagation measurements in what P. Mikhalevsky (SAIC) refers to as the new thin-ice Arctic regime. The hypothesis is that three factors will contribute to the THin-ice Arctic Acoustic Window (THAAW):

(1) The thinning ice in the Arctic is now dominated by one- and two-year ice with greatly reduced pressure ridging, resulting in reduced transmission loss and allowing operation at higher acoustic frequencies than in the past.

(2) Ambient noise in the Arctic is highly variable, with periods of high noise associated with pressure ridging and periods of low noise when the wind is low and the ice is stable. With much reduced pressure ridging, there should be longer and more frequent periods of low noise conditions.

(3) There is still ice cover, however, albeit thin and with reduced areal extent, throughout much of the year that will continue to largely insulate the Arctic ocean from wind and solar forcing, preserving the stable Arctic acoustic channel.

The goal of the THAAW project is to quantify the elements of the sonar equation so that an appropriate basin-scale system for long term acoustic monitoring, communication, and navigation can be designed.

APPROACH

With DARPA funding, SAIC deployed a broadband J15-3 acoustic source and a receiving array in the deep Arctic near the North Pole during April 2013. Both the source and receiver were suspended from the ice and drifted with it. Scripps Institution of Oceanography (SIO), Woods Hole Oceanographic Institution (WHOI), and the Naval Postgraduate School (NPS) augmented the SAIC effort with a bottom-moored Distributed Vertical Line Array (DVLA) receiver (Worcester *et al*., 2009, 2013) deployed close to the Pole. The DVLA consisted of a single 600-m array with 22 Hydrophone Modules. It was programmed to record without interruption for 108 minutes beginning at 1200 UTC six days per week at a sample rate of 1953.125 Hz. The DVLA included 10 Seabird MicroCATs (SBE 37-SM/SMP) to measure temperature and salinity (PI: J. Colosi, NPS), augmenting the temperature measurements made by the Hydrophone Modules.

WORK COMPLETED

The SIO-WHOI DVLA was deployed through the ice at 89º 23.379'N, 062º 35.159'W at Russian ice camp Barneo during 12–15 April 2013. The nominal depth of the subsurface float was 80 m in water 4132 m deep. Following deployment of the DVLA, we were informed that the J15-3 source installed by SAIC had been programmed to transmit beginning at 1200 EDT. The DVLA therefore did not record at the times of the J15-3 transmissions and instead recorded only ambient noise.

On 3 May 2013 we began receiving ALARM messages from the Xeos Kilo Iridium-GPS beacon located on top of the subsurface float, indicating that the mooring had prematurely surfaced. The reported position at the time of surfacing was 88º 50.30'N, 51º 17.91'W, which is 63.4 km from the position at which the THAAW mooring had been deployed. The implication is that the mooring had

failed shortly after deployment, but the subsurface float was trapped beneath the ice preventing the Xeos beacon from obtaining GPS positions and transmitting Iridium messages. The float drifted slowly south toward Fram Strait after surfacing, although there were frequent gaps when no messages were received (Fig. 1). The mooring was successfully recovered on 20 September 2013 at approximately 84º 02.102’N, 003º 03.497’W using the Norwegian Coast Guard icebreaker KV Svalbard. Dr. Hanne Sagen of the Nansen Environmental and Remote Sensing Center (NERSC) in Bergen, Norway, was Chief Scientist and graciously provided the ship time needed to search for and recover the mooring.

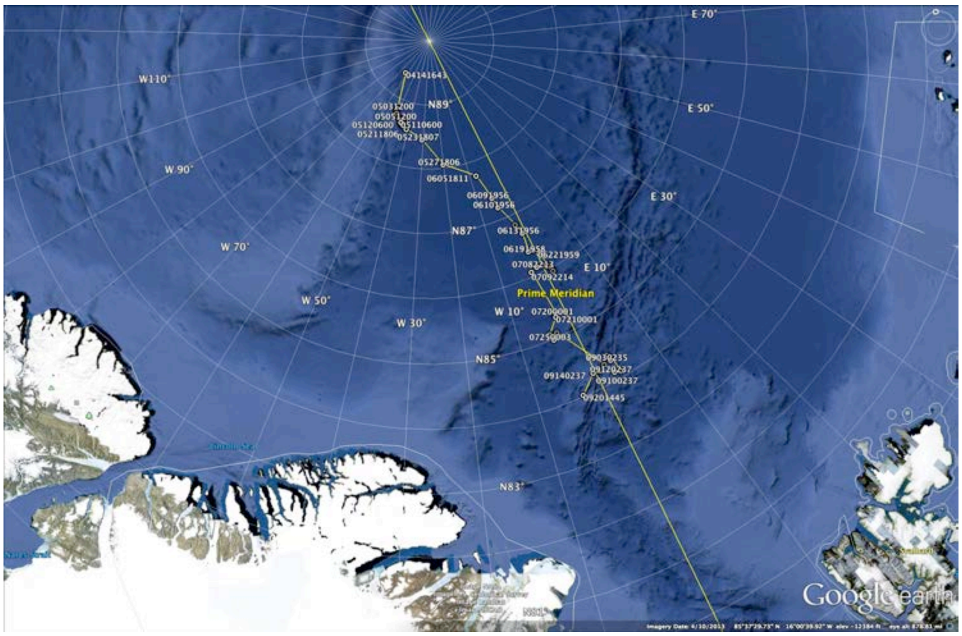

Fig. 1. Drift of the SIO-WHOI THAAW mooring showing the track from deployment at ice camp Barneo on 14 April 2013 until it was sighted on the surface by the KV Svalbard on 20 September 2013. A subset of the GPS positions provided by the GPS-Iridium beacon are labeled in mmddhhmm format.

There were intermittent problems in the inductive communication link between the D-STAR and the Hydrophone Modules, resulting in some lost data. (The cause of the communication problem is now understood and appropriate modifications have been made to eliminate the problem in future DVLA deployments.) In addition, the acoustic data are at times contaminated by strumming of the mooring. We are beginning efforts to objectively identify times when strum is present, so that we can remove the effects of strum on the data when possible or discard contaminated data when necessary. In spite of these problems, the ambient noise data collected by the DVLA provide a rich data set for characterizing the ambient noise field. Significant progress was made during FY2014 in processing and analysis of the ambient noise data.

RESULTS

Preliminary estimates of the distribution of ambient noise power as a function of frequency for each of the Hydrophone Modules in the THAAW array show a broad peak at about 10 Hz. Fig. 2 shows the results at a nominal depth of 252 m, for example. These results are for the entire THAAW data set,

including times contaminated by strumming. They have not yet been corrected for the frequency response of the Hydrophone Modules, which roll off below about 10 Hz.

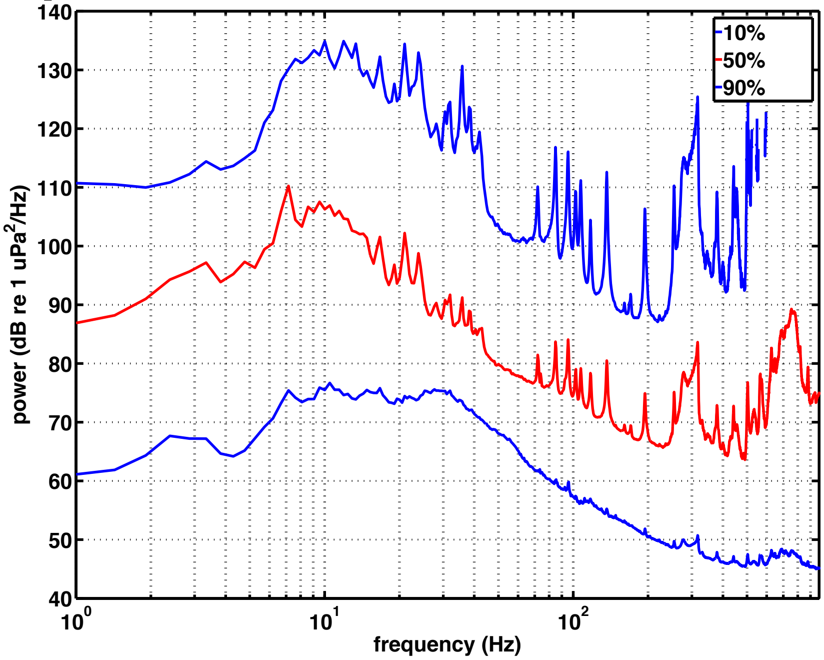

Fig. 2. The 10th, 50th, and 90th percentiles of ambient noise power as a function of frequency at a nominal depth of 252 m for the entire THAAW data set (Hydrophone Module S/N 158).

Ambient noise measurements made during the Fram IV ice camp during April 1982 at a depth of about 90 m show a similar broad peak at about 10 Hz (Dyer, 1984). The 50th percentile of the current measurements at 50 Hz (~ 80 dB re 1 μPa^2/Hz) is comparable to the intermediate level observed in April 1982. While the 10th percentile in Fig. 2 does not appear to be contaminated by strumming, the 50th and 90th percentiles clearly are.

The ambient noise distributions as a function of depth at 50 Hz show slowly increasing levels with depth, except for decreases near the surface and at about 80 m, particularly for the 10th percentile (Fig. 3). The causes of these decreases are unknown. The 90th percentile is clearly contaminated by strum, especially above 200 m.

IMPACT/APPLICATIONS

This research has the potential to affect the design of deep-water acoustic systems in the Arctic, whether for sonar, acoustic communications, acoustic navigation, or acoustic remote sensing of the ocean interior.

RELATED PROJECTS

This project is a joint effort by SIO (P. Worcester), WHOI (J. Kemp), and NPS (J. Colosi). It was designed to augment the SAIC (P. Mikhalevsky) THin-ice Arctic Acoustic Window (THAAW) project, which is one component of the DARPA Assured Arctic Awareness program.

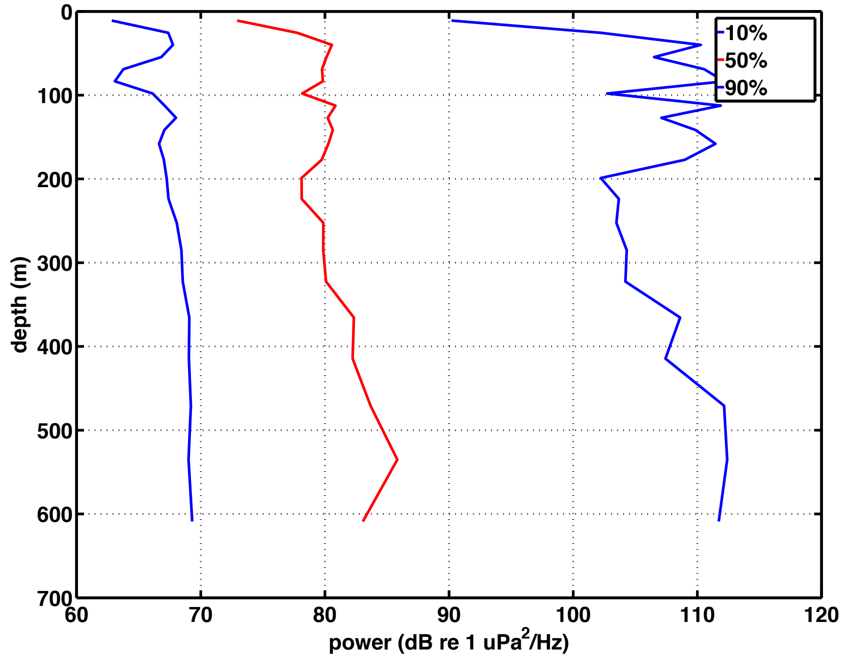

Fig.3. The 10th, 50th, and 90th percentiles of ambient noise power at 50 Hz as a function of depth for the entire THAAW data set.

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